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Multi-band Micropole Antenna Design Using Impedance Change

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임피던스 변화를 이용한 다중대역 마이크로폴 안테나 설계

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ABSTRACT

A multi-band, compact, and complex vehicle roof antenna has become important in terms of car exterior design and multi-functions which include Radio, DAB/DMB, SXM, GNSS, Telematics, and V2X. In this paper, we propose a compact multi-band V2X pole-type roof antenna. Using impedance change characteristic, a single pole antenna which has multiband such as radio, DAB/DMB, telematics, and V2X band is proposed. With two patch antennas for GNSS and SXM, the dimension of a multiband roof antenna is 131x63x37mm only.

Key Words : Impedance(임피던스), V2X Antenna(V2X 안테나), Multi-band Antenna(멀티밴드 안테나), Micropole Antenna(마이크로폴 안테나), Compact Antenna(소형 안테나)

1. Introduction

Vehicle antennas have recently been equipped with a communication system that provides various wireless services such as infotainment, telematics, and driver assistance systems. This covers a wider range of communication functions, including a digital broadcasting receiving function (DAB: Digital Audio Broadcasting, DMB: Digital Media Broadcasting), a location positioning function (GNSS: Global Navigation Satellite System), and a high-speed wireless communication transmission and reception function (LTE: Long Term Evolution) in addition to the conventional radio receiving function.

As various communication functions are gradually added, the integrated antenna located on the vehicle roof has been developed to various specifications and sizes. As various specifications are added, including radio-only specifications (Fig.1(a) 83x52x36mm), Radio+GPS specifications, (Fig.1(b) 131x63x37mm) and Radio+DMB+GPS+3G specifications (Fig.1(c) 135x63x68mm), the volume of the integrated antenna has increased to implement these functions1. In addition, because additional antenna functions will be continuously required in the future according to the V2X legislation and the commercialization of 5G mobile communication networks, an additional volume

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(a) (b) (c)

(a) with Radio only (83x52x36mm),
(b) with Radio, GPS, (131x63x37mm, or Radio, XM, GPS, 3G with inner pole),
(c) with Radio, DMB, GPS, 3G, (135x63x68mm)

Fig. 1 Micropole type antenna size for vehicle by specification (size excluding pole)

Fig. 2 Transparent view (drawing) of inner (Telematics) and outer (Radio) coils for multiband application on a single pole

increase is expected.

The demand for vehicles equipped with micropole integrated antennas such as small Sport Utility Vehicles (SUVs), Recreational Vehicles (RVs), Compact Utility Vehicles (CUVs), and other small hatchbacks is sharply increasing. Exterior design is another important factor in selecting a vehicle, in addition to functions, performance, and price. Thus, a small integrated antenna that does not spoil the aesthetics of small vehicles is required. The development of a small antenna is also required to expand the design possibilities of new vehicles or to develop antennas with new specifications in the future.

Moreover, as the floor area of the integrated antenna increases, the water leakage resistance decreases. Minimizing the floor area of the integrated antenna is necessary to make it water-tight.

Because vehicle sales regions, communication bandwidths, and the functions required for each region are diverse, the specifications for each function of the integrated antenna have diversified. For example, SXM is supported in North America, DAB is supported in Europe, and DMB is supported in South Korea. Mobile communication frequency bandwidths also differ by region.

In addition, under conventional antenna specifications (Radio+DMB+GPS+3G), the size of the antenna can increase due to the addition of functions such as telematics, as shown in Fig. 1(c). When various band antennas such as Radio, DMB/DAB, LTE/V2X are implemented in one coil and the GNSS patch antenna and SXM patch antenna are applied to the integrated micropole antenna, the integrated antenna can be designed at the size of a conventional small micropole antenna.[1,2]

As shown in Fig. 2, because the micropole coil was previously divided into an outer coil and an inner coil, multiple bandwidths can be implemented in one coil. In this method, when the pole is bent, there is a possibility that the resonance characteristics of the antenna can change due to a change in the contact or gap between the outer coil and the inner coil.

Herein, we propose a multi-band antenna based on the principle of impedance change using an outer coil pitch change of the micropole antenna. For this purpose, in Chapter 2, a multi-band pole antenna design is proposed, and in Chapter 3, design verification is performed through simulation of the antenna based on the proposed impedance breakpoint. Finally, Chapter 4 describes the conclusions.

2. Multi-band Antenna Design

2.1 Typical Multi-band Antenna Structure

Recently, more advanced antennas carry XM and 3G specifications in addition to the conventional Radio+GPS (Fig. 1(b)) without a size increase. As shown in Fig. 2, the additional functions were implemented by inserting an inner coil into the outer coil, which has been implement the radio function, including the implementation of a 3G communication bandwidth.

In this case, it is difficult to implement functions due to interference between coils, and due to the bending characteristics of the micropole antenna, the antenna characteristics can change when the outer coil and the inner coil come into close proximity or contact with each other.2 In addition, the inner coil is inserted to implement the functions, which increases the cost.

2.2. Multi-band Antenna Using Impedance Breakpoint

Herein, we propose a multi-band pole antenna with DMB/DAB, 3G/4G LTE, and V2X specifications with one pole antenna using the impedance breakpoint, as shown in Fig. 3.

The advantage of this technology is the capability to integrate all of the above-mentioned specifications without increasing the antenna size. Thus, although the conventional instrument size (Fig. 2(b)) only allows for Radio/GPS/XM/3G implementation, when our proposed technology is applied, Radio/DMB/GNSS/SXM/LTE/V2X specifications can be implemented with the same instrument size.

When the impedance of the antenna changes due to a change in the material or shape of the antenna, resonance is newly formed or the resonance characteristics are changed.5 A multi-band can be formed using these characteristics. The proposed technology is implemented by adjusting the pitch of the helical coil and changing the impedance of the antenna to form the desired communication bandwidth. A multi-band can be implemented by forming a pitch control point (breakpoint) corresponding to desired bandwidths. In this case, it is possible to reuse instruments such as the exterior case of a conventional composite antenna, the base components, and the exterior structure of a pole antenna, reducing the mold manufacturing cost and the mechanical reliability certification cost. Specifications can be added without changing product configuration and structure. Thus, it is possible to add a desired frequency bandwidth (DMB, DAB) while using the conventional antenna structure as it is.

Worldwide configuration is possible because radio, DMB (DAB), GNSS, SXM, LTE, and V2X specifications can be extended without performing product configurations classified according to required specifications and regions.

Furthermore, because the structure of the conventional small micropole antenna can be maintained without changing the size or shape of the antenna, it is possible to facilitate the exterior design

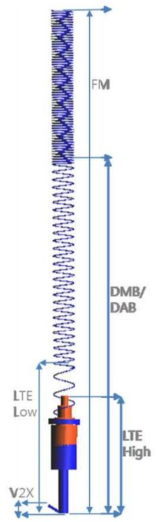
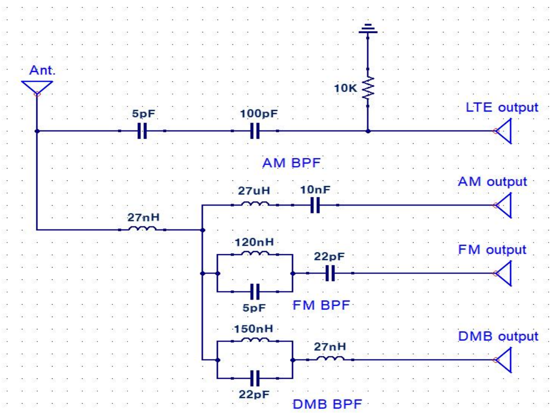


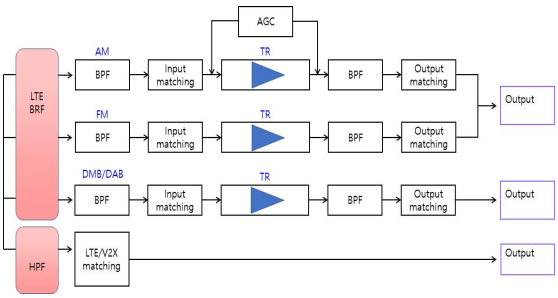
Fig. 3 3D model of proposed multiband pole antenna (Radio, DAB/DMB, LTE, and V2X)

of vehicles without increasing the size of the antenna, filling a niche in the small SUV/CUV market which requires a miniaturized micropole antenna.

In the case of the conventional antenna, because the outer coil and the inner coil are separately used, if the antenna is bent or its shape is changed, there is a high probability of defects. This problem is likely to lead to poor progression. Because the proposed technology implements multi-bands using one coil, these potential defects are eliminated. As the conventional technology requires additional insertion of an inner coil, the addition of parts and processes is essential. Moreover, a separate structure must be inserted between the inner coil and the outer coil to prevent defects. This increases the number of parts and processes required, thus increasing the product cost. Because the structure proposed in this study is manufactured with only one coil, there is no increase in the number of parts. In addition, because the process is simple, the working hours and cost are reduced.



(a) AM, FM, DMB, LTE/V2X signal distribution circuit using RLC filter



(b) Block diagram including pre-amplifiers and matching circuit

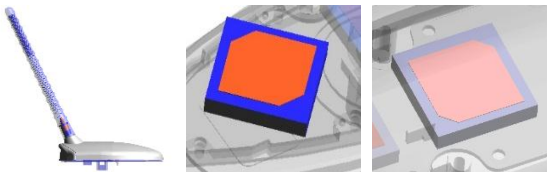
Fig. 4 Antenna signal distribution circuit design

2.3 Signal Distribution (Filter), Preamplifier, and Impedance Matching Circuit Design

To implement AM, FM, DAB/DMB, and LTE/V2X with one antenna, a Diplexer or a circuit for signal distribution is required. Fig. 4(a) shows a signal distribution circuit using an RLC filter. Subsequently, as shown in Fig. 4(b), signals are distributed to the three feeder cables for AM/FM, DMB, and LTE/V2X through the pre-amplification and matching stage, and further connected to the H/U and modem. In the case of LTE/V2X, to reduce cost, a cable is commonly used, and signals are distributed to each modem using a separately configured diplexer at the front end of the modem.

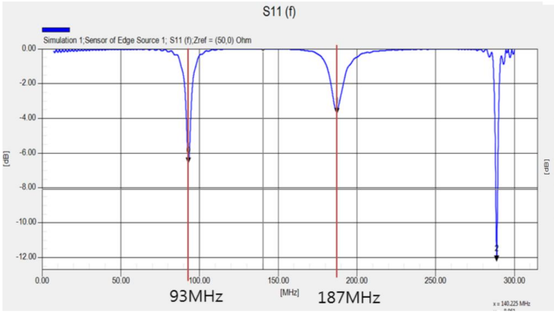
3. Simulation

Fig. 5 shows the 3D model of the antenna and the mounting location for EM simulation. For the simulation, a SEMCAD EM Simulator and a real vehicle 3D model were utilized, and S-parameters, radiation patterns, and isolation were simulated.[6]

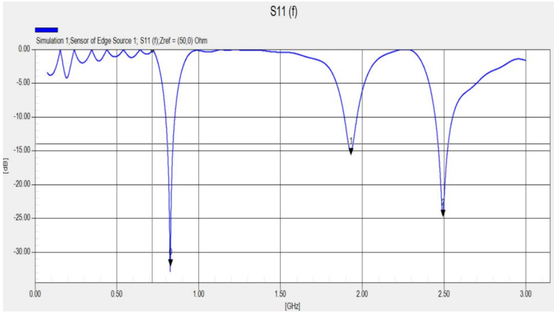


(a) (b) (c)

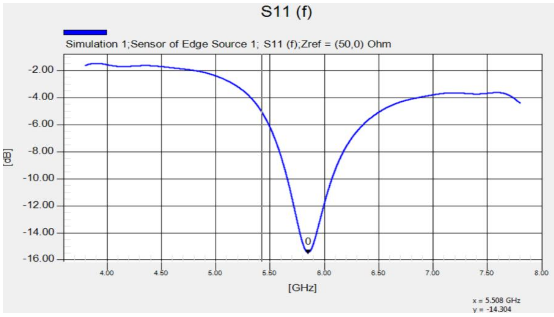
Fig. 5 3D model of (a) proposed multiband pole antenna (Radio, DAB/DMB, LTE, and V2X), (b) GNSS antenna, (c) SXM antenna, and (d) complex antenna set on a car roof for simulation



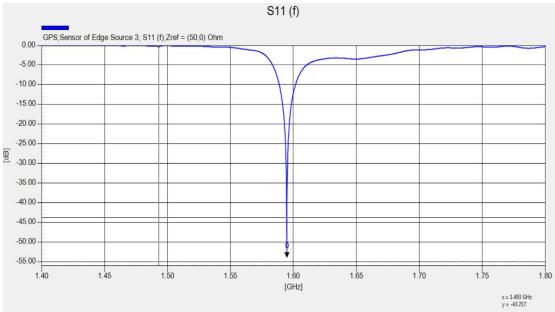
(a) FM, DMB/DAB



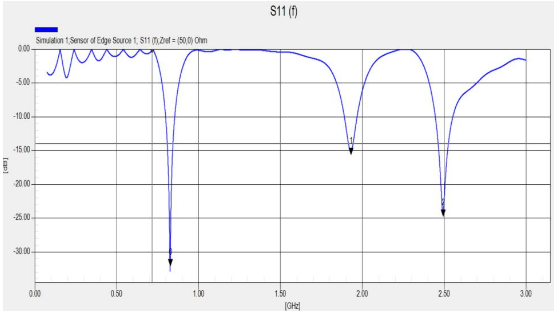
(b) LTE



(c) V2X



(d) GNSS



(e) SXM

Fig. 6 S-parameter simulation result for (a)~(e) frequency band (matching circuit and filter are not included in simulation)

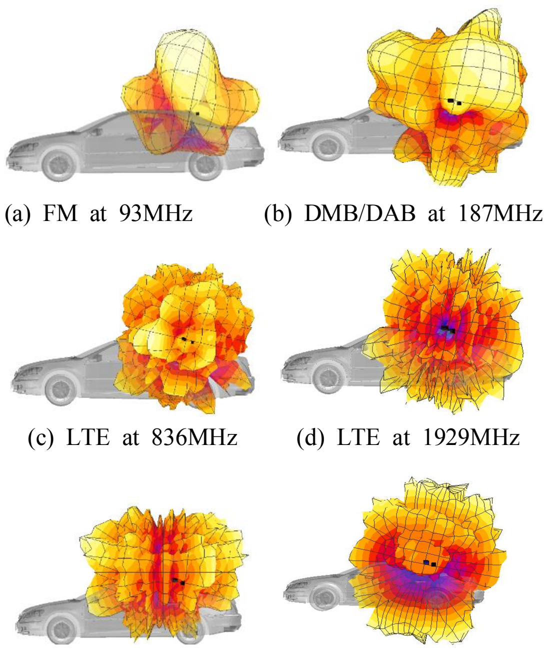
Fig. 6 shows the results of the S-parameter simulation. The antennas were designed to enable resonance to occur in the FM, DAB/DMB, LTE low-band, LTE high-band, V2X, GNSS, and SXM antenna frequency bands, respectively.

Fig. 7 shows the radiation pattern simulation results. Fig. 7 shows the radiation pattern at the resonance point of each frequency bandwidth as a result of simulation analysis by applying a small micropole antenna designed for vehicle modeling.

In an antenna with several functions coexisting in a small space, because each signal can act as an interference signal, mutual interference between antennas is important. In particular, unlike other antennas that are only responsible for receiving, a telematics (LTE/3G) antenna, which is also responsible for transmission, can also affect other antennas and receivers. Fig. 8 shows the simulation results of the isolation between the LTE antenna, SXM, and GNSS. The isolation between each bandwidth is 20dB or less in the corresponding bandwidth.

4. Conclusion

Herein, we designed and simulated a multi-band micropole antenna using the impedance breakpoint



(a) FM at 93MHz (b) DMB/DAB at 187MHz

(c) LTE at 836MHz (d) LTE at 1929MHz

(e) V2X at 5850MHz (f) GNSS at 1590MHz

Fig. 7 Radiation Pattern Simulation Result

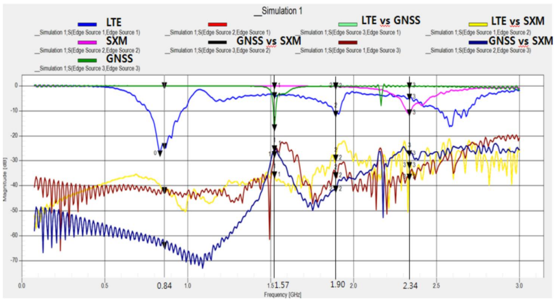


Fig. 8 Isolation simulation result for LTE, GNSS, and SXM

of multiple pitches. As various communication functions in the vehicle are added, there is an increasing need for multi-band antennas. This multi-band integrated antenna is crucial for miniaturization, integration, and improvement of vehicle exterior design. The implementation of radio, DAB/DMB, LTE, and V2X antennas into a single pole will expand design possibilities, provide wide latitude for integrated antennas in next-generation vehicles, and improve antenna reliability.

The size of the micropole integrated antenna proposed in this study is 131x63x37mm, including SXM and GNSS patch antennas, as confirmed through simulation with the same size as the conventionally mass-produced antenna.

In the future, the micropole integrated antenna proposed in this study will be fabricated and the simulation results and the actual results will be compared and evaluated.

Acknowledgments

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